

# **TECHNICAL MEMORANDUM**

March 1989

## **LAKE OKEECHOBEE PESTICIDE MONITORING REPORT, 1987**

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## EXECUTIVE SUMMARY

Lake Okeechobee is Florida's largest and most important lake, providing essential water supply, flood control, recreation, and wildlife benefits to south Florida. Lake Okeechobee is also a key feature of the Kissimmee-Okeechobee-Everglades ecosystem and as such, needs to be protected for future generations. Part of the protection process is an evaluation of the water quality, including an investigation into the extent of pesticide contamination present. Pesticide monitoring is necessary due to the extensive agricultural activities around the lake and in the drainage basins.

The level, or concentration, of a toxic compound in the environment depends on the quantity introduced into the environment and the processes which influence its fate. "Transport" processes tend to distribute chemicals among the atmospheric, aquatic, and soil environments depending on the affinity of the compound for each compartment. "Transformation" processes within each compartment chemically alter pollutants to forms of lesser, equivalent, or sometimes greater toxicity. These processes occur at rates which are specific to each chemical and to each environmental compartment. The sum of these processes and their interactions determines the environmental fate and consequent exposure of biota to a toxic pollutant.

For the aquatic environment, pesticides can enter by: a) runoff or leaching directly into surface or ground water; b) erosion of soil containing adsorbed compounds; c) drift from aerial or land applications; or d) direct application via an aquatic weed control program.

For this investigation, six sampling sites located in Lake Okeechobee were sampled for pesticides in August 1987. Water and sediment samples were taken at each site and analyzed for 61 pesticides, herbicides, and degradation products. This set of compounds included numerous chemicals which are currently being utilized in

the agricultural areas as well as compounds presently banned or currently restricted to non-crop uses.

No detectable pesticide residues were present in any of the water or sediment samples taken from Lake Okeechobee. During previous water and sediment analysis performed from 1976 through 1980, the following compounds were detected: chlordane, DDE, DDD, DDT, dieldrin, endrin, and 2,4-D. Although the same locations were not sampled in this study as in the previous monitoring efforts, it appears that the chlorinated hydrocarbon pesticide residues have decreased. However, lower detection limits for the current analysis would have provided a better insight into this conclusion.

Diquat and 2,4-D have been utilized for aquatic weed control on the Lake since the 1960's. Initial applications were by the Florida Game and Freshwater Fish Commission, with the South Florida Water Management District taking over this role in 1980. The current use of diquat and 2,4-D does not appear to be contributing detectable quantities of residues in the areas sampled for this study.

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## ABSTRACT

For this investigation, six sampling sites located in Lake Okeechobee were sampled for pesticides in August 1987. Water and sediment samples were taken at each site and analyzed for 61 pesticides, herbicides, and degradation products. This set of compounds included numerous chemicals which are currently being utilized in the agricultural areas as well as compounds presently banned or currently restricted to non-crop uses. No detectable pesticide residues were present in any of the water or sediment samples taken from Lake Okeechobee. During previous water and sediment analysis performed from 1976 through 1980, the following compounds were detected: chlordane, DDE, DDD, DDT, dieldrin, endrin, and 2,4-D. Although the same locations were not sampled in this study as in the previous monitoring efforts, it appears that the chlorinated hydrocarbon pesticide residues have decreased. However, lower detection limits for the current analysis would have provided a better insight into this conclusion.

Diquat and 2,4-D have been utilized for aquatic weed control on the Lake since the 1960's. Neither compound was detected during the current sampling. The current use of diquat and 2,4-D does not appear to be contributing detectable quantities of residues in the areas sampled for this study.

### Key Words:

pesticide, herbicide, residue, Lake Okeechobee

## INTRODUCTION

Lake Okeechobee is Florida's largest and most important lake, providing essential water supply, flood control, recreation, and wildlife benefits to south Florida. Lake Okeechobee is also a key feature of the Kissimmee-Okeechobee-Everglades ecosystem and as such, needs to be protected for future generations. Part of the protection process is an evaluation of the water quality, including an investigation into the extent of pesticide contamination present. This pesticide monitoring is necessary due to the extensive agricultural activities in the lake's drainage basin.

The level, or concentration, of a toxic compound in the environment depends on the quantity introduced into the environment and the processes which influence its fate. "Transport" processes tend to distribute chemicals among the atmospheric, aquatic, and soil environments depending on the affinity of the compound for each compartment. "Transformation" processes within each compartment chemically alter these chemicals to forms of lesser, equivalent, or sometimes greater toxicity. These processes occur at rates which are specific to each chemical and to each environmental compartment. The sum of these processes and their interactions determines the environmental fate and consequent exposure of biota to a toxic pollutant.

Agricultural application constitutes the major route by which pesticides can enter the environment. For the aquatic environment, pesticides and herbicides can enter by: a) runoff or leaching directly into surface or ground water; b) erosion of soil containing adsorbed compounds; c) drift from aerial or land applications; or d) direct application via an aquatic weed control program.

Once in the aquatic environment, the ability of some pesticides and herbicides to move through the food chain results in higher concentrations at each trophic level. This bioconcentration or bioaccumulation of pesticide chemicals is dependent on



several factors. The rate of chemical bioaccumulation and the final amount are functions of the particular species, a number of physical and chemical environmental factors, and the nature and quantity of the contaminant entering the water column. Environmental factors affecting contaminant uptake include pH, temperature, and the total amount of solids in the water on which contaminants can sorb. Additionally, the physical-chemical properties of the contaminants affect bioaccumulation. The bioaccumulation of various pesticides in fish is influenced by chemical polarity and water solubility. There is a qualitative inverse correlation between water solubility and fish bioaccumulation, with bioaccumulation decreasing as the solubility of the pesticide increases.

Bioaccumulation can also be considered as the net difference of biological uptake and elimination, and thus, may be related to metabolism or the rate of specific biochemical processes. The physical and chemical differences of various organisms are important factors in determining uptake or bioaccumulation of chemical contaminants. Differences in the organism's surface area to volume ratio and the gross differences in the surface composition impact the amount and rate of bioaccumulation. For example, the size and age of the fish species can affect the accumulation of chemical residues. The ecological significance of pesticide bioaccumulation depends on the compound and organism involved.

The possibility does exist that any compound found in the sediment could enter the food chain through the actions of benthic organisms. These organisms provide an ecological link between the sediment and the upper trophic levels in the food chain. The movement of any chemical would depend on its physical-chemical properties as well as the species of animal involved.

The introduction of pesticides into the environment could pose several different kinds of health threats. These adverse effects are commonly considered as either acute effects, that develop quickly after exposure but usually are of short duration,

or chronic effects which may appear after a delay, often of years, but then persist for extended periods. Chronic adverse effects occur as a result of sustained exposures, but are much more difficult to evaluate than are acute effects. With an excessive single exposure, the result will be either a systemic pesticide poisoning or a topical lesion.

The South Florida Water Management District (SFWMD) first monitored pesticides in Lake Okeechobee in 1976 during a cooperative U.S. Geological Survey (USGS) program. During this cooperative program, baseline water quality data were collected at various locations not already sampled by other specific projects within the SFWMD. This information aided in the documentation of water quality conditions in actively developing drainage basins and documented the quality of water at major water control structures. One objective of the monitoring was to identify existing or potential problems relating to toxic substances. In addition to pesticides, PCB's (polychlorinated biphenyl), and PCN's (polychlorinated naphthalene) were also analyzed. Sediment sampling in Lake Okeechobee was performed in 1976 and 1977. During 1976, samples were taken near the center and in the south end at Pelican Bay, the Rim Canal near Pahokee, and South Bay. The southern sites are near Ritta and Torry Islands, which were formerly used to grow crops. In 1977, five stations were sampled in the lake, and nine stations were sampled around the agricultural islands. At this time, the soil/sediment was also sampled from these islands. The pesticide residues detected in the sediment samples consisted of the chlorinated hydrocarbon types. The compounds detected included: chlordane, DDD, DDE, DDT, dieldrin, and endrin. At the time of sampling, dieldrin and DDT had been recently banned. The maximum values detected at the lake stations occurred on the former agricultural islands. Excluding these extremely high residues, the other sediment residue concentrations were similar to levels found on a national basis (Pfeuffer, 1985).

Surface water sampling in Lake Okeechobee was conducted in 1979 and 1980. In November 1979, as part of the SFWMD/ USGS cooperative program, samples were taken in Fisheating Bay, two miles west of Port Mayaca, and at the supply intake for the City of Pahokee. At the last station, the only compound detected was the herbicide 2,4-D at 0.02 µg/L (Pfeuffer, 1985). The 2,4-D compound is one of the most extensively used herbicides, having major turf, forestry, industrial, and aquatic uses as well as crop and pastureland uses. The concentration of this residue was below the State Class I surface water standard of 100 µg/L (FAC 17-3.091(21)(c)).

Pesticide analyses were also performed as part of the requirements for the Temporary Operating Permit issued by the Florida Department of Environmental Regulation. Florida Statutes, Chapter 403, requires a permit for discharges from stationary installations, i.e. pumps, into waters of the state. The purpose of this project was to monitor the water quality so the additional information could be used to determine if the discharges were in compliance with the water quality standards. Water samples were taken during September 1979 and August 1980 at five stations in the lake. These stations were located at mid-lake and at the public water supply intakes for Okeechobee, Belle Glade, South Bay, and Clewiston. The herbicide 2,4-D was found at all stations during the 1979 sampling trip but not during the 1980 event. The highest 2,4-D level recorded was 4.36 µg/L at the Okeechobee Public Water Supply intake. However, this value is still far below the State Class I standard. No other compounds were detected (Pfeuffer, 1985).

The bioaccumulation of pesticides has been demonstrated in a SFWMD monitoring program that was undertaken in the early 1970's. In this program, chlorinated hydrocarbon pesticide residues have been analyzed in freshwater fish from SFWMD waterways. The period 1970-73 was committed to pilot programs to establish a monitoring network. Routine collections were made in 1978 and 1983 with minor adjustments and additions to sample locations and fish species.

Freshwater fish were collected for these analyses from the western shore of Lake Okeechobee in 1978, and from the north and south portions of the lake in 1983. The chlorinated hydrocarbon pesticide residues detected during the 1978 survey consisted of DDT and its derivatives, dieldrin, chlordane, and toxaphene (Milleson, 1980). The levels of chlorinated hydrocarbon pesticide residues in freshwater fish collected in 1983 were related to the intensity of agricultural land use in the watershed. The north site fish were collected in the littoral zone from north of the Kissimmee River east to S-135, while the south site collection area was the Rim Canal and edge of the littoral zone near Torry Island. DDT and its derivatives and chlordane were found in all specimens examined, while dieldrin, heptachlor, and PCB's were sporadically present. Concentrations were considerably higher in the south lake samples than all other areas surveyed. However, even from the more contaminated areas, i.e. south Lake Okeechobee, none of the pesticides detected were present in concentrations exceeding Food and Drug Administration tolerance limits for edible flesh or Environmental Protection Agency environmentally dangerous threshold limits. None of the other ten scanned chlorinated hydrocarbon pesticides were detected (Milleson, 1988).

To determine if there has been any changes in the concentration of previously detected compounds or any gross contamination of the lake by contemporary compounds, this monitoring program was established. An evaluation will be made of the potential water quality and wildlife impacts from any detectable pesticide residues.

## **MATERIALS AND METHODS**

For this investigation, six lake sampling sites were sampled on August 17, 1987 (Figure 1). These stations coincide with sampling stations from the District's Lake Okeechobee Limnetic and Littoral Zone Water Quality Monitoring Program

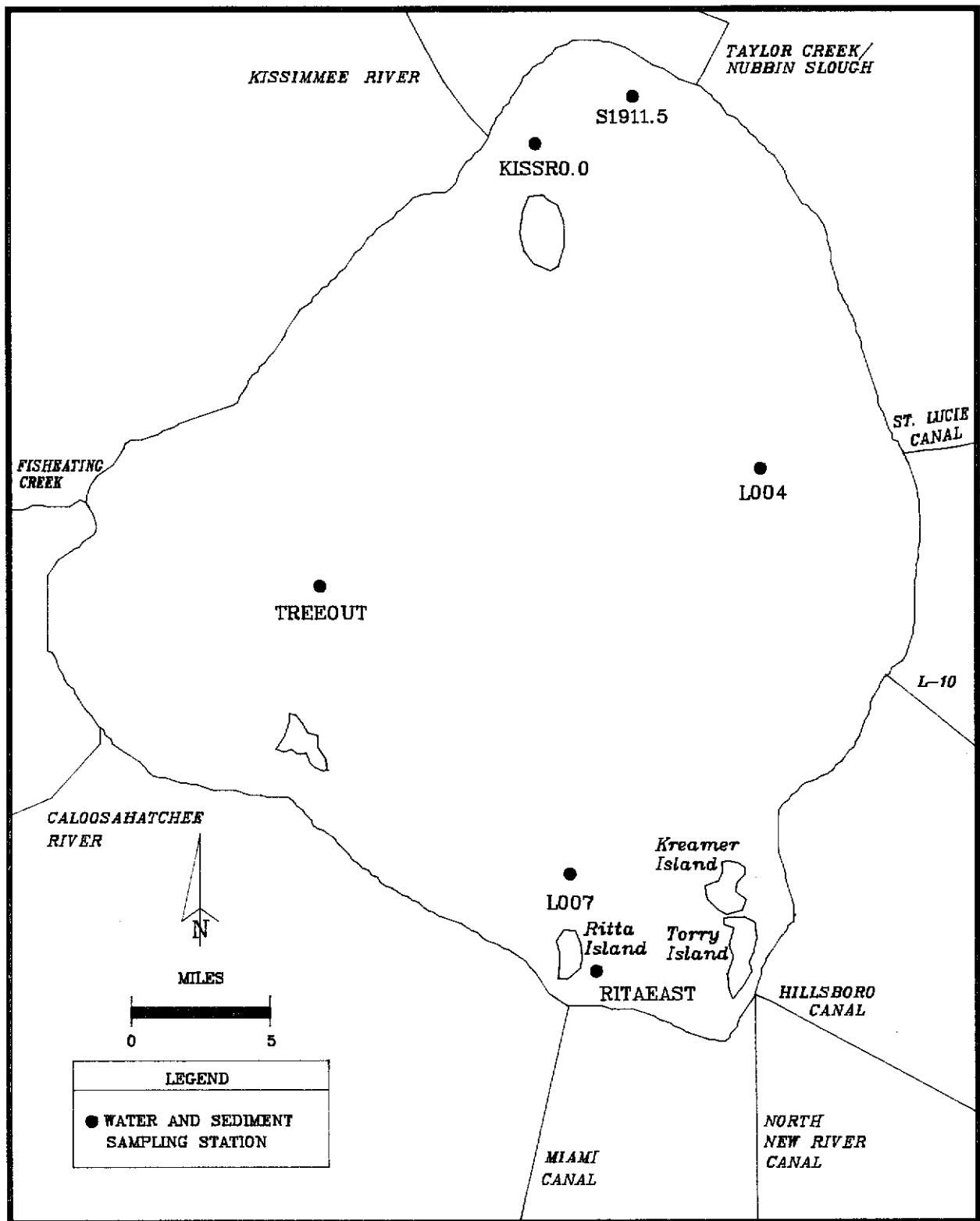


Figure 1. Lake Okeechobee Pesticide Monitoring Program

(Germain and Shaw, 1988). These sampling sites were chosen to represent the different areas of the lake. Water and sediment samples were taken at each site in sample containers specifically prepared for pesticide analysis and placed on ice. Sample bottles were provided by the contract laboratory. The water samples were surface grab samples. The top layer of sediment was obtained using a petite Ponar dredge. One split sample was utilized as a quality assurance check. The water samples were analyzed by the University of Miami, Division of Chemical Epidemiology Laboratory (Miami, Florida). The sediment samples were analyzed by Environmental Science and Engineering, Inc. (Gainesville, Florida).

The analyzed compounds consisted of 61 pesticides, herbicides, and degradation products (Table 1). Appendix A provides some descriptive information on each of the compounds. The current set of compounds include numerous chemicals which are currently being utilized in the agricultural areas as well as compounds presently banned or currently restricted to non-crop uses. Table 2 provides a list of representative Florida registered pesticides for a selected list of crops or application sites. Pesticides which were listed in this table but were not monitored, were due to a lack of suitable analytical methodology, or minimum environmental impact, or lack of significant usage in the drainage basin.

## RESULTS AND DISCUSSION

None of the water and sediment samples taken at the stations had any detectable residues. During the water and sediment analysis performed from 1976 through 1980, the following compounds were detected: DDE, DDD, DDT, chlordane, dieldrin, endrin, and 2,4-D. The detection of these compounds during previous sampling was due to these compounds still being utilized, or the result of the persistent nature of these compounds in the environment. All uses for DDT were canceled in 1973. By 1980, chlordane could only be utilized for termite control, with all other uses phased

TABLE 1. PESTICIDES ANALYZED IN SURFACE WATER AND SEDIMENT SAMPLES

<u>Pesticide</u>	<u>Sediment</u>	<u>Surface Water</u>	<u>Pesticide</u>	<u>Sediment</u>	<u>Surface Water</u>
2,4-D	36.4 - 260 <sup>1</sup>	2.0 <sup>2</sup>	*Fonofos/ Dyfonate	25 - 180	0.06
2,4-DP/Dichlorprop	6.26 - 44.7	0.8	*Glyphosate	NA	100.0
2,4,5-T	6.14 - 43.9	0.6	Guthion/ Azinphos-Methyl	25.1 - 178	1.0
2,4,5-TP/Silvex	6.39 - 45.7	0.4	Heptachlor	6.27 - 51.7	0.00
*Alachlor	80 - 660	0.02	Heptachlor Epoxide	15.7 - 129	0.00
*Aldicarb	0.05 - 0.37	2.0	*Kelthane/ DicofoI	31 - 260	0.01
Aldrin	6.27 - 51.7	0.002	Lindane/ BHC, Gamma	6.27 - 51.7	0.00
*Ametryn	25.1 - 178	10.0	Malathion	21.5 - 178	0.06
*Atrazine	25.1 - 178	0.10	*Methamidophos	250 - 1800	0.20
*Benomyl	NA <sup>3</sup>	20.0	*Methomyl	170 - 1200	20.0
BHC, Alpha	6.27 - 51.7	0.002	Methoxychlor	25.1 - 207	0.02
BHC, Beta	6.27 - 51.7	0.004	*Methyl Bromide	19 - 140	1.0
BHC, Delta	6.27 - 51.7	0.003	Methyl Parathion	25 - 180	0.06
*Bromacil	100 - 710	0.02	*Metholachlor	63 - 520	0.02
*Carbaryl/ Sevin	55 - 390	NA	*Metribuzin	25 - 180	0.00
*Carbofuran	92 - 650	10.0	*Mevinphos	25.1 - 178	0.10
Chlordane	6.27 - 51.7	0.01	*Monocrotophos/ Azodrin	25.1 - 178	1.0
*Chloropicrin	0.194 - 1.39	1.0	*Oxamyl	98 - 700	2.0
*Chlorpyrifos	25.1 - 178	0.06	*Paraquat	1200	3.0
*Chlorothalonil	60 - 490	0.004	Parathion	25.1 - 178	0.06
Diazinon	25.1 - 178	0.06	Perthane	63 - 520	0.02
Dieldrin	15.7 - 129	0.003	Phorate	100 - 711	0.03
*Diquat	1400	4.0	P,P'-DDD	6.27 - 51.7	0.00
Endosulfan, Alpha	15.7 - 129	0.007	P,P'-DDE	15.7 - 129	0.00
Endosulfan, Beta	6.27 - 51.7	0.008	P,P'-DDT	15.7 - 129	0.01
Endosulfan Sulfate	6.27 - 51.7	0.017	*Prometryn	25 - 180	10.0
Endrin	15.7 - 129	0.007	*Simazine	25 - 180	0.10
*Endrin Aldehyde	6.27 - 51.7	0.018	Toxaphene	639 - 5280	0.05
Ethion	25 - 180	0.10	Trifluralin	72 - 590	0.01
Ethoprop	25.1 - 178	0.06	Trithion/ Carbophenothion	63 - 520	0.10

<sup>1</sup> RANGE OF MINIMUM DETECTION LIMIT IN UG/KG-DRY WEIGHT OR PPB<sup>2</sup> MINIMUM DETECTION LIMIT IN UG/L OR PPB<sup>3</sup> PARAMETER NOT ANALYZED DUE TO LACK OF SUITABLE ANALYTICAL METHOD

\*COMPOUND ANALYZED FOR THE FIRST TIME WITHIN LAKE OKEECHOBEE

TABLE 2. REPRESENTATIVE FLORIDA REGISTERED COMPOUNDS FOR SOME SELECTED CROPS OR APPLICATION SITES.

Compounds	Aquatic Plants			Beans			Bromeli	Cabbage	Celery	Citrus	Corn	Cucumber	Dairy	Eggplant	Endive	Lettuce	Non-Crop Areas			Okra	Ornamental	Parsley	Pasture	Potatoes	Radishes	Rice	Sod	Sugar cane	Squash	Tomatoes
	-	-	X	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Alachlor	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aldicarb	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	X	-	-
Ametryn	-	-	-	-	-	X	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Anilazine	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X
Atrazine	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	X	M	-	-
Benomyl	-	-	X	-	M	X	-	X	-	X	-	X	-	-	-	-	-	-	-	-	M	-	-	-	-	X	-	X	X	-
Bromacil	-	-	-	-	-	M	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Captaf	-	-	X	-	X	X	X	-	-	X	-	X	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	X
Captafol	-	-	-	-	-	M	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carbaryl	-	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	M	-	-	-	-	X	-	-	-	X
Carbofuran	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorobenzilate	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-
Chloropicrin	-	-	-	X	M	X	X	M	-	X	X	M	-	X	X	X	X	-	-	-	M	-	-	-	-	X	-	X	X	M
Chlorothalonil	-	-	X	X	M	-	X	X	-	-	X	X	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	X
Chlorpyrifos	-	-	X	X	-	X	M	X	X	X	M	X	X	X	X	X	X	-	-	-	M	-	-	-	-	-	-	-	-	X
2,4-D	M	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-	X	-	X	-	-	X	-	-	-	-
2,4-DP/Dichloroprop	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Demeton	-	-	-	X	X	-	-	-	-	X	-	-	-	X	X	X	X	-	-	-	X	-	-	-	-	-	-	-	-	X
Diazinon	-	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	M	-	X	X	-	X	-	X	X	X
Dicamba	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	-	-
Dechlorobenzil	X	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-
Diquat	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Diuron	-	-	-	-	-	M	X	-	-	-	X	-	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-
Endothall	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Endosulfan	-	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	-	M	-	-	-	-	-	-	-	-	M
Endrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethion	-	-	X	-	-	M	X	X	-	X	X	X	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	X
Ethoprop	-	-	X	-	-	X	X	X	-	-	X	X	-	-	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	-
Fluridone	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fenofos	-	-	X	X	-	-	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Glyphosate	M	-	-	X	X	X	X	X	X	X	X	X	-	X	-	-	X	-	-	-	M	-	-	-	-	-	-	-	-	X
Guthion	-	-	X	X	X	X	X	X	X	X	-	X	-	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Kelthane/Dicofol	-	-	X	-	-	M	X	-	-	-	X	X	-	X	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	X

KEY: PESTICIDES THAT ARE UNDERLINED WERE ANALYZED DURING THIS PROGRAM  
 "A" PESTICIDES NOT REGISTERED FOR THIS CROP OR SITE  
 "M" REPRESENTS A MAJOR USE OF THIS CHEMICAL FOR THIS SITE  
 "X" REPRESENTS A LABELLED USE OF THIS CHEMICAL FOR THIS SITE



TABLE 2 CONTINUED. REPRESENTATIVE FLORIDA REGISTERED COMPOUNDS FOR SOME SELECTED CROPS OR APPLICATION SITES.

Compounds	Aquatic Plants	Beans	Broccoli	Cabbage	Celery	Citrus	Corn	Cucumber	Dairy	Eggplant	Endive	Lettuce	Non-Crop Areas				Okra	Ornamental	Parsley	Pasture	Potatoes	Radishes	Rice	Sod	Sugar cane	Squash	Toma- toes
Lindane	-	X	X	X	X	-	-	X	-	-	-	X	X	X	-	-	M	-	-	-	-	-	-	-	-	X	X
Linuron	-	-	-	-	M	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Malathion	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	M	M	X	X	X	X	X	X	-	X	X
Mancozeb	-	-	-	-	X	-	M	M	-	M	M	M	-	-	-	-	-	-	-	-	-	M	-	-	-	M	M
Maneb	-	X	X	M	X	-	X	X	-	X	X	X	-	-	-	-	-	X	-	-	-	X	-	-	-	X	X
Metaxyl	-	X	X	X	-	M	X	X	-	X	-	M	-	-	-	-	M	X	-	-	-	X	-	-	-	M	X
Methamidophos	-	-	X	-	M	-	-	M	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	M
Methomyl	-	X	X	M	M	X	M	M	X	M	M	X	X	X	X	X	-	M	X	-	-	X	-	-	-	M	M
Methoxychlor	-	X	X	X	-	-	X	X	X	X	X	X	-	-	-	-	-	X	-	-	-	X	-	-	-	X	X
Methyl Bromide	-	-	X	-	M	M	-	M	-	M	-	X	X	X	X	X	-	M	-	-	-	-	-	-	-	M	M
Methyl Parathion	-	X	X	X	X	-	X	X	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
Metolachlor	-	X	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
Metribuzin	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	M	M
Mevinphos	-	X	X	X	M	X	X	X	-	X	M	X	-	-	-	-	-	-	X	-	-	X	-	-	-	X	X
Monocrotophos/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	M	-	X
Azinrin	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naled	-	X	X	X	X	-	-	X	X	X	-	X	X	X	-	-	X	-	-	-	X	-	X	-	-	X	X
Oxamyl	-	-	-	-	X	X	-	M	-	X	-	-	-	-	-	-	M	-	-	-	-	-	-	-	-	M	X
Paraquat	-	X	X	X	-	M	X	M	-	M	M	M	-	-	-	-	-	M	-	-	-	-	-	-	X	M	M
Parathion	-	X	X	X	X	X	X	X	-	X	X	X	-	-	-	-	X	X	-	-	-	M	X	X	X	X	X
Phorate	-	X	-	-	-	-	M	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	M	-	X
Prometryn	-	-	-	-	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simazine	M	-	-	-	-	X	-	-	-	-	-	-	X	-	-	-	-	M	-	-	-	-	-	X	X	-	-
Terbacil	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-
Trifluralin	-	X	X	X	X	X	-	X	-	-	-	-	X	X	-	-	X	M	-	-	-	-	-	-	X	-	X
Trithion	-	X	-	-	-	X	X	X	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	X	X
Carbophenothion	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc Phosphide	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X	-	-	-	-	-	-	-	M	-	-
Zineb	-	X	X	X	X	X	X	X	-	X	-	X	-	-	-	-	X	X	-	-	-	X	-	-	-	X	X

KEY:

"Alachlor" PESTICIDES THAT ARE UNDERLINED WERE ANALYZED DURING THIS PROGRAM

"-" PESTICIDES NOT REGISTERED FOR THIS CROP OR SITE

"M" REPRESENTS A MAJOR USE OF THIS CHEMICAL FOR THIS SITE

"X" REPRESENTS A LABELLED USE OF THIS CHEMICAL FOR THIS SITE

out. All chlordane sales were finally suspended in 1987. Dieldrin followed the same course, since all uses except termite control were canceled by 1974 and all sales suspended in 1987. Endrin is currently restricted to non-crop areas with a phase-out of registered uses beginning in 1979. Currently, the residues have apparently dissipated to below the levels of detection. However, the variation in the detection limits of the sediment samples makes this comparison difficult. Some of the detection limits were higher than previous levels of residues found in some of the lake sediment samples. The range in detection limits is the result of differences in the sediment types. Interferences within and the binding capacity of the sediment will cause variations in the ability to recover pesticides. This results in variations in detection limits when using the same analytical technique for different samples. The compounds which have never been monitored within the Lake during previous SFWMD programs are identified in Table 1.

Diquat and 2,4-D have been utilized for aquatic weed control on the Lake since the 1960's. Initial applications were by the Florida Game and Freshwater Fish Commission with the SFWMD taking over this role in 1980. Neither compound was detected during the current sampling.

## CONCLUSIONS

The water and sediment samples collected within Lake Okeechobee in 1987 did not contain detectable residues of pesticides at the sampled locations.

The current use of diquat and 2,4-D does not appear to be contributing detectable quantities of residues in the areas sampled for this study.

Although the same locations were not sampled in this study as in the previous monitoring efforts, it appears that the chlorinated hydrocarbon residues have decreased since they have been banned or agricultural uses eliminated. However, lower detection limits for the current analysis would have provided a better insight into this conclusion.

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# **Appendix A**

**A brief descriptive paragraph for each compound analyzed.**

**2,4-D:** 2,4-D is a phenoxy-aliphatic non-restricted use selective herbicide registered for use on rice, sugarcane, corn, ornamental turf and lawn grasses, pastures, and non-crop areas as well as aquatic applications (NPIRS, 1988). Reported half-lives in environmental waters range from a few days to several months depending on factors such as temperature, pH, light intensity, formulation and oxygen concentration. 2,4-D is relatively rapidly degraded in the environment with residue half-lives generally not exceeding several weeks in plants, soil, and water (US DHHS, 1981). It is eliminated rapidly by animals and is not bioaccumulated. 2,4-D is moderately toxic with an acute oral LD<sub>50</sub> for rats of 375 mg/Kg body weight (Toxicity Category II)(Berg, 1985).

**2,4-DP:** 2,4-DP or dichlorprop is a phenoxy-aliphatic systemic herbicide used for brush control on ornamental turf and lawn grasses, right-of-way, and other non-crop sites (NPIRS, 1988). 2,4-DP is slightly toxic with an acute oral LD<sub>50</sub> for rats of 800 mg/Kg body weight (Toxicity Category III)(Berg, 1985).

**2,4,5-T:** 2,4,5-T is a phenoxy-aliphatic selective herbicide with no registered uses in Florida (NPIRS, 1988). Uses in the United States are restricted at this time (US DHHS, 1981). 2,4,5-T is moderately toxic with an acute oral LD<sub>50</sub> for rats of 500 mg/Kg body weight (Toxicity Category II)(Berg, 1985). During a runoff event, 2,4,5-T could be transported in appreciable proportion in the water (Stewart, 1975).

**2,4,5-TP:** 2,4,5-TP or silvex is a phenoxy-aliphatic herbicide which had registered uses for rice, range, and non-crop sites (fencerows, industrial sites, vacant lots, etc.). All uses in the United States are cancelled at this time. 2,4,5-TP is slightly toxic with an acute oral LD<sub>50</sub> for rats of 650 mg/Kg body weight (Toxicity Category III)(Berg, 1985). During a runoff event, 2,4,5-TP could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Alachlor:** Alachlor is an acetanilide compound used as a preemergence herbicide for controlling annual grasses and certain broadleaf weeds in corn, peas, beans, and potatoes (Thomson, 1983; NPIRS, 1988). Alachlor is slightly toxic with an acute oral LD<sub>50</sub> for rats of 1800 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Soil half-lives in the lab range from 4 to 21 days and half-lives in the field of 18 and 15 days have been reported (Cohen *et al.*, 1984). During a runoff event, alachlor could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Aldicarb:** Aldicarb is a carbamate systemic restricted use insecticide, acaricide and nematicide for soil use on citrus, potatoes, sugarcane, and ornamental crops (NPIRS, 1988). Aldicarb (Temik 10G) is highly toxic by oral, dermal, and inhalation routes of exposure (Toxicity Category I), with an acute oral LD<sub>50</sub> for rats of 7.0 mg/Kg body (Berg, 1985). Aldicarb is highly toxic to mammals, birds, estuarine/marine organisms, and freshwater organisms. LC<sub>50</sub> values for the bluegill sunfish and rainbow trout have been reported as 50 ug/L and 560 ug/L, respectively (EPA, 1984a). Aldicarb exhibits a half-life in water from 5 to 15 days. Aldicarb degrades in soil under both aerobic and anaerobic conditions, with a half-life of 1 to 28 weeks (US DHHS, 1981). Aldicarb has been found to leach in fine to coarse textured soils, including those soils with a high organic matter content, and may reach ground water (EPA, 1984a). During a runoff event, aldicarb could be transported in appreciable proportion in the water (Stewart, 1975).

**Aldrin:** Aldrin is a chlorinated hydrocarbon restricted use insecticide used primarily to control soil insects (Berg, 1985). All of these uses were cancelled in October 1974 with the exception of termite control. As of August 1987 all sales of aldrin were suspended. Its manufacture has been discontinued in the United States. Aldrin has an acute oral LD<sub>50</sub> for rats of 40-60 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Aldrin is highly toxic to aquatic organisms and birds (EPA, 1986a). Volatilization half-lives of less than a few days are likely in aquatic systems when sorption to biota and subsequent biotransformation to dieldrin do not occur rapidly. Photosensitized and photooxidation processes may also be important fates for aldrin, but insufficient information is available to assess how general and reliable these processes are for environmental assessments (Callahan *et al.*, 1979). During a runoff event, aldrin could be transported in appreciable proportion in the soil (Stewart, 1975).

**Ametryn:** Ametryn is a non-restricted use triazine compound with selective terrestrial herbicide use on potatoes, corn, sugarcane, bananas, plantains, pineapple, grapefruit, oranges, and non-crop areas (NPIRS, 1988). Technical ametryn (pure) is slightly toxic with an acute oral LD<sub>50</sub> for rats of 1,750 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Ametryn has a low LC<sub>50</sub> toxicity for fish. Ametryn, based on published adsorption partition coefficient values for this compound and similar compounds, would be moderately persistent in soils (half-life between 20 and 100 days) with the compound being slightly or moderately mobile. During a runoff event, ametryn could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Atrazine:** Atrazine is a non-restricted use triazine compound with selective terrestrial herbicide use on pineapple, sugarcane, corn, rangelands, ornamental turf and lawn grasses and non-crop areas (NPIRS, 1988). Atrazine is only slightly toxic with the technical compound having an acute oral LD<sub>50</sub> for rats of 1,780 mg/Kg body weight (Toxicity Category III)(Berg, 1985). Degradation is very dependent on soil type, moisture content, atrazine concentration, temperature, and soil depth. Although atrazine is somewhat persistent because of strong adsorption to clay or organic matter, it is degraded to hydroxy-atrazine, as well as other metabolites, in soils, water, tolerant plants, and animals (US DHHS, 1981). The half-life of atrazine is very site specific but is approximately 10 days in the water and 45 days in the soil. Leaching is minimal in clay and high-organic soils due to adsorption. The low to moderate vertical mobility of atrazine reduces the possibility of ground water contamination. Contamination due to runoff is more likely (US DHHS, 1981). During a runoff event, atrazine could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Benomyl:** Benomyl is a non-restricted use benzimidazole carbamate compound (Buchel, 1983). Benomyl is a systemic fungicide with registered uses on citrus, bananas, mangos, papayas, pineapple, beans, avocados, rice, tomatoes, celery, cucumbers, sugarcane, squash, cabbage, ornamental plants, turf and lawn grasses (NPIRS, 1988). Benomyl is almost non-toxic with an acute oral LD<sub>50</sub> for rats of greater than 9,590 mg/Kg body weight (Toxicity Category IV)(US DHHS, 1981). Aqueous degradation of benomyl is relatively rapid, with complete conversion to its major degradation product, methyl 2-benzimidazolecarbamate (MBC) in one week. The half-life of benomyl residues are approximately 3 to 6 months on turf and 6 to 12 months on bare soil. Benomyl is essentially immobile in soil with no leaching or movement from treatment site (US DHHS, 1981). During a runoff event, benomyl could be transported in appreciable proportion in the soil (Stewart, 1975).



**BHC (Hexachlorocyclohexane or Benzene Hexachloride):** BHC is a chlorinated hydrocarbon insecticide composed of several isomers. Technical BHC is a mixture of alpha, beta, gamma, and delta-isomers. Production of technical BHC was suspended in 1976. All domestic registrations for BHC have been voluntarily cancelled and the registrants have amended their registrations and reformulated their products to incorporate lindane (at least 99 percent pure gamma isomer) rather than BHC (US DHHS, 1981). The fate of the alpha, beta, and delta-isomers in aquatic systems is determined by their availability to biotransformation processes. Although sorption to suspended hydrosoil and biota is not extensive, sorption is probably an important process for ultimately transporting BHC to anaerobic hydrosoils where transformations occur due to the lack of chemical and biological transformation in aerobic systems (Callahan et al., 1979).

**Bromacil:** Bromacil is a substituted uracil compound used as a pre- and postemergent herbicide on citrus, pineapple, and numerous non-crop areas (NPIRS, 1988). Bromacil is almost non-toxic with an acute oral LD<sub>50</sub> for rats of 5,200 mg/Kg body weight (Toxicity Category IV)(Berg, 1985). Bromacil is degraded at a moderate rate in soil, with an estimated half-life of approximately 7 months. Bromacil is highly mobile in soil, leaching to depths of 18 to 24 inches (US DHHS, 1981). During a runoff event, bromacil could be transported in appreciable proportion in the water (Stewart, 1975).

**Carbaryl:** Carbaryl is an insecticidal carbamate compound registered for use on rice, tomatoes, celery, peppers, broccoli, cabbage, beans, corn, cucumbers, eggplant, endive, lettuce, parsley, radish, squash, ornamental plants and trees, ornamental turf and lawn grasses, non-crop areas, and citrus crops (NPIRS, 1988). Carbaryl is moderately toxic with an acute oral LD<sub>50</sub> for rats of 225 mg/Kg body weight (Toxicity Category II). Carbaryl is extremely toxic to aquatic invertebrates and certain estuarine organisms. An LC<sub>50</sub> value for Daphnia pulex of 6.4 ppb has been reported. It is moderately toxic to fish and has only low toxicity to birds. LC<sub>50</sub> values for the bluegill sunfish and rainbow trout have been reported as 6.76 ppm and 1.95 ppm, respectively. The half-life appears to range from 7 to 28 days in aerobic and anaerobic soils, respectively (EPA, 1984b). During a runoff event, carbaryl could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Carbofuran:** Carbofuran is a broad spectrum restricted use systemic carbamate insecticide and nematicide registered for use on potatoes, corn, rice, sugarcane, squash, and cucumbers (NPIRS, 1988). Carbofuran is highly toxic with an acute oral LD<sub>50</sub> for rats of between 3.8 and 34.5 mg/Kg body weight (Toxicity Category I). Carbofuran is characterized as very highly toxic to fish, highly toxic to freshwater invertebrates, and very highly toxic to birds. Carbofuran degrades fairly slowly in un-sterile, neutral, or acid aerobic soils, with half-lives ranging from one to eight weeks. It is more stable in sterile soil, and unstable under alkaline conditions. Under anaerobic conditions, carbofuran is more stable and may take twice as long to degrade. Carbofuran is mobile in soil, particularly sandy soil with a high percolation rate. It has been found in shallow aquifers under or near treated fields at levels up to 50 ppb (EPA, 1984c). Runoff studies indicate losses of less than 2 percent with carbofuran residues remaining in water rather than sediment (US DHHS, 1981).

**Chlordane:** Chlordane is a chlorinated hydrocarbon previously used as a contact insecticide. Chlordane is moderately toxic with an acute oral LD<sub>50</sub> for rats of between 283 to 590 mg/Kg body weight (Toxicity Category II)(Buchel, 1983). Technical chlordane is a mixture of numerous isomers of chlordane and closely related compounds and by-products. About one-half of the composition consists of the

two major isomers of chlordane; no other individual component exceeds about one-tenth of the total product. The oil solution type formulation was used almost exclusively for subterranean termite control applications, and emulsifiable concentrates, granules, dusts, and wettable powders for termite control and certain agricultural purposes (Berg, 1985). However, all sales were suspended by the EPA in August of 1987, pending the outcome of the evaluation of potential human health risks. Volatilization, sorption to hydrosoil, and bioaccumulation are important fates for the chlordane isomers in aqueous environments. The chlordane isomers also undergo photosensitized isomerization, but no information is available to determine whether such reactions may occur in aquatic systems. Although biotransformations of chlordane may be important for the ultimate transformation of chlordane, these processes are likely to be very slow in the environment (Callahan *et al.*, 1979). During a runoff event, chlordane could be transported in appreciable proportion in the soil (Stewart, 1975).

**Chloropicrin:** Chloropicrin is a restricted use soil fumigant used for the control of weeds, nematodes, and certain fungal diseases (Thomson, 1983). Registered uses include pineapples, potatoes, rice, cabbage, endive, lettuce, sugarcane, ornamental plants, tomatoes, celery, cucumbers, eggplant, radishes, squash, corn, broccoli, peppers, ornamental turf and lawn grasses, non-crop areas, and citrus (NPIRS, 1988). Chloropicrin is moderately toxic with an acute oral LD<sub>50</sub> for rats of 250 mg/Kg body weight (Toxicity Category II) (Berg, 1985).

**Chlorothalonil:** Chlorothalonil is a broad spectrum chlorinated hydrocarbon fungicide. Registered uses include papayas, ornamental plants, celery, corn, cucumbers, squash, tomatoes, cabbage, ornamental turf and lawn grasses, potatoes, beans, and broccoli (NPIRS, 1988). Chlorothalonil is almost non-toxic with an acute oral LD<sub>50</sub> for rats of >10,000 mg/Kg body weight (Toxicity Category IV) (Berg, 1985). However, chlorothalonil is highly toxic to fish and aquatic invertebrates, with low amounts of residues affecting the reproduction of these organisms. Chlorothalonil breaks down in aerobic soil with a half-life of 1 to 2 months. This breakdown appears to be primarily the result of microbial degradation, since chlorothalonil is relatively stable to hydrolysis and photolysis. Chlorothalonil is immobile in most soil types, except sand in which it is moderately mobile (EPA, 1984d).

**Chlorpyrifos:** Chlorpyrifos is a non-restricted use organophosphorus insecticide with registered uses on bananas, squash, eggplant, cucumbers, tomatoes, broccoli, cabbage, corn, citrus, ornamental turf and lawn grasses, peppers, endive, lettuce, potatoes, radishes, beans, ornamental plants, and non-crop areas (NPIRS, 1988). Chlorpyrifos is moderately toxic with an acute oral LD<sub>50</sub> for rats of 118 mg/Kg body weight (Toxicity Category II) (US DHHS, 1981). Chlorpyrifos is extremely toxic to fish, birds and other wildlife. It is highly toxic to honey bees (EPA, 1984e). Hydrolysis in water occurs very readily above pH 8.0 and occurs least readily at about pH 6.0. Hydrolysis appears to be the main route of degradation. Half-lives generally in the range of 80 to 100 days have been observed in various soils. Chlorpyrifos is not leached in soil (US DHHS, 1981).

**DDD:** DDD, although considered a degradation product of DDT, is also a chlorinated hydrocarbon insecticide formerly used on many fruits and vegetables. The major fate processes for DDD in aquatic environments are bioaccumulation and sorption to hydrosoils and biota. Volatilization will also be an important process for loss of DDD from aquatic systems, with DDD half-lives on the order of a few days to several weeks. DDD is quite stable to chemical transformations in aquatic

environments, and biotransformation is probably the process resulting in the ultimate degradation of DDD in the environment (Callahan et al., 1979).

**DDE:** DDE is formed as a degradation product of DDT and is not manufactured as a commercial product. The major fate processes for DDE in aquatic environments are bioaccumulation and sorption to hydrosol and biota. Laboratory studies suggest that in aquatic environments, DDE may have volatilization half-lives of several hours and photolysis half-lives of several days; the observed persistence of DDE in such environments may be due to the fact that DDE is mainly formed from DDT under biological conditions in which DDE in the sorbed state is then not available for volatilization or photolysis (Callahan et al., 1979).

**DDT:** DDT is a chlorinated hydrocarbon compound formerly used as an insecticide. All uses have been cancelled as of January 1, 1973. Technical DDT comprises mainly a mixture of two DDT isomers: PP' and OP' with the PP' isomer being the dominant isomer. There is ample evidence to demonstrate that DDT is very persistent in the environment. The dominant fate processes in aquatic environments are volatilization and sorption to biota and hydrosol, with the importance of sorption being determined by the amount of suspended particulate available in the water body. The ultimate transformation of DDT in the aquatic environment is probably by biotransformation, although one study indicates that indirect photolysis may also be a significant loss process for DDT in a natural water, with a photolysis half-life on the order of a week. Photolysis of DDT in the gas phase has also been reported, but since DDT has been widely found throughout the biosphere, atmospheric transformations appear to be slow. There is also abundant evidence to demonstrate that bioaccumulation of DDT is a significant process in the environment (Callahan et al., 1979).

**Diazinon:** Diazinon is a non-restricted use organophosphorus insecticide and nematicide with a variety of registered uses. These include field, fruit, vegetable, ornamentals, livestock, range, pasture, lawns, household outdoor and indoor applications. Diazinon is slightly toxic with an acute oral LD<sub>50</sub> for rats of 1,186 mg/Kg body weight (Toxicity Category III)(Berg, 1985). However, diazinon is very highly toxic to birds, fish, and aquatic invertebrates (EPA, 1985a). During a runoff event, diazinon could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Dieldrin:** Dieldrin is a chlorinated hydrocarbon insecticide. The manufacture of dieldrin was discontinued in the U.S. since 1974 with all uses except termite control cancelled (Berg, 1985). Sales in the U.S. were suspended in August of 1987 and all registrations may be cancelled. Dieldrin was previously used for the control of soil insects, public health insects, and many other pests. Dieldrin is highly toxic with an acute oral LD<sub>50</sub> for rats between 40 to 87 mg/Kg body weight (Toxicity Category I)(Buchel, 1983). The literature information indicates that dieldrin is persistent in the environment. The important fate processes in aquatic environments are sorption to hydrosol, bioaccumulation, and volatilization; the latter process may have half-lives of several hours to several days in some aquatic systems. Although direct photolysis of dieldrin in water is slow (1.5 to 2 months), photosensitized processes may result in photolysis if sensitizers are available in aquatic environments. Although dieldrin is quite resistant to biotransformation, this process will probably be an important fate for dieldrin in hydrosol and biota (Callahan et al., 1979).

**Diquat:** Diquat is a bipyridylium compound registered as a non-selective non-crop weed killer, a general aquatic herbicide and as a preharvest top killer or

desiccant of seed crops. Registered uses include sugarcane, ornamental turf and lawn grasses, potatoes, and non-crop areas (NPIRS, 1988). Diquat is moderately toxic with an acute oral LD<sub>50</sub> for rats of 230 mg/Kg body weight (Toxicity Category II). Diquat is very rapidly absorbed by foliage and is resistant to removal by rain. An important property of diquat is its very rapid and complete inactivation by soil, due to its cationic nature. When bound to soil, diquat is very persistent but biologically unavailable (Beste, 1983). Since leaching from soil is apparently negligible, diquat residues are also considered immobile (Burns and Audus, 1970; Simsiman *et al.*, 1976). Residues of diquat are reported to disappear from water in 4 to 13 days with the rapid disappearance from water attributed largely to adsorption by hydrosoil, suspended particulate matter, and aquatic plants, i.e. suitable sorbents (Frank and Comes, 1967). For aquatic applications, major losses apparently occur through dispersion, microbial degradation, photodegradation and uptake by phytoplankton and other suspended matter, but eventually residues are incorporated into the hydrosoil (Joyce and Ramey, 1986). During a runoff event, diquat could be transported in appreciable proportion in the soil (Stewart, 1975).

**Endosulfan:** Endosulfan is a chlorinated hydrocarbon insecticide and acaricide registered for use on beans, tomatoes, celery, corn, cucumbers, pineapples, peppers, potatoes, eggplant, lettuce, squash, broccoli, cabbage, citrus, and ornamental plants (NPIRS, 1988). Endosulfan is moderately to highly toxic with an acute oral LD<sub>50</sub> for rats between 30 and 110 mg/Kg body weight (Toxicity Category I and II) (Verschuere, 1983). Technical endosulfan is a mixture of the two stereoisomeric forms, the alpha and the beta forms. Data are incomplete regarding the important processes for determining the fate of endosulfan in aquatic systems. The hydrolysis half-life of endosulfan at 20°C is about a month at pH 7 and about six months at pH 5.5. Other information suggests that photolysis, oxidation, biodegradation, sorption, and volatilization may be occurring under some environmental conditions, but data for predicting the rates and relative importance of these processes in aquatic systems are not available (Callahan *et al.*, 1979). During a runoff event, endosulfan could be transported in appreciable proportion in the soil (Stewart, 1975).

**Endosulfan Sulfate:** Endosulfan sulfate is thought to be the corresponding cyclic sulfate from the oxidation of either isomer of endosulfan. The sulfate also appears as a metabolite of endosulfan during biotransformations (Callahan *et al.*, 1979; Buchel, 1983).

**Endrin:** Endrin is a restricted use chlorinated hydrocarbon insecticide with a registered use on non-crop areas (NPIRS, 1988). Endrin is highly toxic with an acute oral LD<sub>50</sub> for rats between 7 and 15 mg/Kg body weight (Toxicity Category I) (Berg, 1985). Little information is available for evaluating the fate of endrin in aquatic systems. Photolysis and biotransformation of endrin occur under environmental conditions, but no data are available to assess the rates of these processes in aquatic environments; biotransformation will also be affected by the microbial types and populations available to utilize endrin. No information on the sorption or volatilization of endrin from aquatic systems is available, although bioaccumulation does appear to be significant with concentration factors on the order of 10<sup>3</sup> to 10<sup>4</sup> (Callahan *et al.*, 1979). The half-life for endrin in soil is generally in excess of two years. Endrin residues are not appreciably leached. Residues are sorbed to soil particulates and appreciable transport may occur from soil erosion and runoff (US DHHS, 1981).

**Endrin Aldehyde:** Endrin aldehyde is a transformation product of endrin of which no information has been found to evaluate the fate of endrin aldehyde in aquatic systems (Callahan et al., 1979).

**Ethion:** Ethion is a non-restricted use organophosphorus insecticide and acaricide used to control a broad spectrum of insects and mites on citrus, tomatoes, beans, cucumbers, eggplant, squash, corn, and ornamental plants (NPIRS, 1988). Ethion is highly toxic with an acute oral LD<sub>50</sub> for rats of 24.4 mg/Kg body weight (Toxicity Category I). Ethion is highly toxic to freshwater fish and very highly toxic to freshwater invertebrates. Ethion is not expected to move into water supplies, and does not persist long in the environment. Aquatic monitoring studies rarely show evidence of ethion either in water samples or organisms, while in soil, ethion has a reported half-life of less than two months (EPA, 1982). During a runoff event, ethion could be transported in appreciable proportion in the soil (Stewart, 1975).

**Ethoprop:** Ethoprop is a restricted use organophosphorus insecticide and nematocide with registered uses on citrus, cabbage, corn, sugarcane, cucumbers, beans, bananas, pineapples, potatoes, ornamental turf and lawn grasses (NPIRS, 1988). Ethoprop is moderately toxic with an acute oral LD<sub>50</sub> for rats of 56.2 mg/Kg body weight (Toxicity Category II). Ethoprop is characterized as very highly toxic to birds, marine/estuarine crustaceans, and marine/estuarine fish species. Ethoprop is not expected to contaminate drinking water supplies. It degrades fairly rapidly with half-lives of 3 to 56 days in soil. Increases in soil temperature tends to increase the dissipation rate. However, ethoprop is very mobile in sandy soil and has a potential for contaminating ground water in areas of sandy soil with a high water table (EPA, 1985b).

**Fonofos:** Fonofos or dyfonate is an organophosphorus soil insecticide with some formulations classified as restricted use. Registered uses include beans, broccoli, cabbage, corn, potatoes, radishes, sugarcane, and tomatoes (NPIRS, 1988). Fonofos is highly toxic with an acute oral LD<sub>50</sub> for rats between 3.16 and 18.5 mg/Kg body weight (Toxicity Category I). Fonofos is moderately to highly toxic to birds, and highly toxic to freshwater fish and salt water organisms. Fonofos is immobile in sandy loam and silt loam soils but is mobile in quartz sand. It decomposes in aerobic soils by microbes with a half-life of 3 to 16 weeks. Fonofos is non-volatile from soil but volatile from water. Fonofos is moderately persistent (EPA, 1985c). During a runoff event, fonofos could be transported in appreciable proportion in the soil (Stewart, 1975).

**Glyphosate:** Glyphosate is a broad spectrum, postemergent, translocated herbicide with both terrestrial and aquatic applications. Registered uses include avocados, rice, sugarcane, radishes, corn, broccoli, cabbage, tomatoes, lettuce, carrots, celery, citrus, cucumbers, squash, eggplant, peppers, potatoes, ornamental turf and lawn grasses, and non-crop areas as well as control of emergent type aquatic weeds (NPIRS, 1988). Glyphosate is slightly toxic with an acute oral LD<sub>50</sub> for rats of 4300 mg/Kg body weight (Toxicity Category III) (Berg, 1985). Field studies on 11 different soils, covering a full range of soil types and geographic areas, indicated an average half-life for glyphosate of two months. Other studies have reported half-lives of 17 to 19 weeks for sandy soil and three weeks in silt loam (Ghassemi et al., 1982). Adsorption of glyphosate to soil reduces its mobility through leaching and surface runoff (Sprankle et al., 1975). Microbial degradation is the major route of degradation of glyphosate in water with a half-life of approximately seven weeks (Ghassemi et al., 1982). During a runoff event, glyphosate could be transported in appreciable proportion in the soil (Stewart, 1975).

**Guthion:** Guthion or azinphos-methyl is a restricted use organophosphorus insecticide and acaricide with registered uses on tomatoes, celery, cucumbers, sugarcane, eggplant, broccoli, cabbage, peppers, potatoes, beans, citrus and ornamental plants (NPIRS, 1988). Guthion is highly toxic with an acute oral LD<sub>50</sub> for rats of 4.4 mg/Kg body weight (Toxicity Category I). Guthion exhibits both low soil mobility and low leaching potential in a variety of soil types. In sandy soils guthion dissipates in the field fairly rapidly and is metabolized by microorganisms (EPA, 1986b). The half-life of guthion in water ranged from over 36 days at 60°C to about 7 days at 40°C both at pH 8.6. Increasing the pH past 9 abruptly dropped those half-lives to about one-tenth of the original values at 60°C and 40°C. Residues of guthion appear to generally degrade fairly rapidly on crops and in the environment, but there is evidence that wide variations in the decline rate may occur on different crops and under various environmental conditions (US DHHS, 1981). During a runoff event, guthion could be transported in appreciable proportion in the soil (Stewart, 1975).

**Heptachlor:** Heptachlor is a restricted use chlorinated hydrocarbon insecticide. In 1975, the use of heptachlor for certain pests on agricultural crops was suspended due to its potential carcinogenicity leaving only registration for subterranean termite control (Berg, 1985). However, sales in the U.S. were suspended in August of 1987 and all registrations may be cancelled. Heptachlor is moderately toxic with an acute oral LD<sub>50</sub> for rats between 158 and 208 mg/Kg body weight (Toxicity Category II). Heptachlor is extremely toxic to aquatic organisms and birds (EPA, 1986c). The major fate of heptachlor in the solution phase of aquatic systems will be hydrolysis to give 1-hydroxychlorde (1-HC) with a half-life of about one to three days; 1-HC will then be biotransformed to give 1-hydroxy-2,3-chlorde epoxide (1-HCE). Although literature information also indicates that heptachlor photolysis, volatilization, and sorption to hydrosols may also occur in aquatic environments, no data are available to compare these processes with the hydrolysis transformation rate (Callahan *et al.*, 1979). Heptachlor is considered persistent and bioaccumulates. Heptachlor is not expected to leach, since it is insoluble in water and should adsorb to the soil surface; thus it should not reach underground aquifers (EPA, 1986c). During a runoff event, heptachlor could be transported in appreciable proportion in the soil (Stewart, 1975).

**Heptachlor Epoxide:** Heptachlor epoxide is the oxidation product of heptachlor which occurs in soil and in, or on crops when treatments with heptachlor have been made. Heptachlor epoxide is resistant to chemical and biological transformations in aquatic environments, and half-lives of over several years are probable. Although hydrosol sorption and bioaccumulation are not appreciable, they may ultimately be relatively important processes in view of the stability of heptachlor epoxide in the environment. Photosensitized reaction and biotransformations in anaerobic hydrosols are possibly important processes for eventual transformation of heptachlor epoxide in aquatic environments (Callahan *et al.*, 1979).

**Kelthane:** Kelthane or dicofol is a chlorinated hydrocarbon acaricide registered for use on ornamental plants, ornamental turf and lawn grasses, peppers, beans, tomatoes, cucumbers, eggplant, squash, corn, and citrus (NPIRS, 1988). Kelthane is moderately toxic with an acute oral LD<sub>50</sub> for rats between 684 and 1,495 mg/Kg body weight (Toxicity Category II). Kelthane is highly toxic to aquatic organisms and only slightly toxic to birds, mammals, and beneficial insects. Kelthane residues may accumulate in fish as well as some rotational crops. Field studies show that kelthane persists in soils for at least four years after application. Kelthane residues are negligibly mobile in sandy loam soil column leaching studies. The DDT analog

contaminants in kelthane may cause unreasonable adverse effects in certain bird and fish species (EPA, 1984f). During a runoff event, kelthane could be transported in appreciable proportion in the soil (Stewart, 1975).

**Lindane:** Lindane or gamma BHC is a restricted use chlorinated hydrocarbon insecticide/acaricide with registered uses on beans, tomatoes, celery, cucumbers, squash, okra, broccoli, peppers, lettuce, ornamental plants, non-crop areas, and cabbage (NPIRS, 1988). The U.S. production of lindane was halted in 1976, and all unformulated lindane has been imported since that time (US DHHS, 1981). Lindane is moderately toxic with an acute oral LD<sub>50</sub> for rats of 88 mg/Kg body weight (Toxicity Category II). Lindane is slightly to moderately toxic to birds, and highly toxic to some aquatic organisms (EPA, 1985d). The fate of lindane in aquatic systems will be controlled by the availability of and to biotransformation processes. Lindane transformation will be favored in biologically rich, anaerobic environments. Although sorption to suspended hydrosoil and biota is not extensive, sorption is an important process for ultimately transporting lindane to anaerobic hydrosoils where transformation occurs. Hydrolysis and oxidation do not appear to be important fate processes for lindane; data on the photolysis of lindane are contradictory and confusing. Lindane is only slightly bioaccumulated in organisms (Callahan et al., 1979). During a runoff event, lindane could be transported in appreciable proportion in the soil (Stewart, 1975).

**Malathion:** Malathion is an organophosphorus insecticide with registered uses on avocados, rice, tomatoes, mango, lime, celery, corn, cucumbers, eggplant, endive, lettuce, radish, squash, broccoli, cabbage, and citrus (NPIRS, 1988). Malathion is slightly toxic with an acute oral LD<sub>50</sub> for rats of 1375 mg/Kg body weight (Toxicity Category III)(Berg, 1985). In the soil, malathion is relatively non-persistent with 100 percent of the applied product disappearing from the soil within one week. Hydrolysis in water occurs very readily above pH 8.0 and occurs least readily at about pH 5 (Verschueren, 1983). During a runoff event, malathion could be transported in appreciable proportion in the water (Stewart, 1975).

**Methamidophos:** Methamidophos is a restricted use insecticide/acaricide used on a variety of row crops including broccoli, celery, lettuce, cabbage, and potatoes (NPIRS, 1988). Residues of methamidophos also arise from acephate use as methamidophos is a metabolite of acephate. Methamidophos (90 percent technical) is highly toxic with an acute oral LD<sub>50</sub> for rats of 15.6 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Foliar half-life for methamidophos can be up to 11 days. Foliar degradation products are non-cholinesterase-inhibiting compounds which are thought to be of lesser toxicological concern. No data are available on the degradation in natural water, however, in buffered solutions degradation is rapid with half-lives less than seven days. Limited data indicates that methamidophos leaches readily in soil, but degrades rapidly in the process, with half-lives less than six days. During a runoff event, methamidophos could be transported primarily in water (US DHHS, 1981).

**Methomyl:** Methomyl is a restricted use carbamate compound used as a broad spectrum insecticide and nematocide with registered uses on avocados, peppers, potatoes, tomatoes, mango, celery, corn, cucumbers, eggplant, endive, papayas, beans, lettuce, parsley, squash, broccoli, cabbage, citrus, ornamental plants, and non-crop areas (NPIRS, 1988). Methomyl is highly toxic with an acute oral LD<sub>50</sub> for rats between 17 and 24 mg/Kg body weight (Toxicity Category I)(Berg, 1985). Methomyl degraded in aerated river water exposed to sunlight, with a half-life of slightly less than seven days. Degradation in soil occurs with a half-life of between

4 and 5 weeks, producing CO<sub>2</sub> and other materials. Only slight leaching tendencies and insignificant runoff ability have been demonstrated (US DHHS, 1981).

**Methoxychlor:** Methoxychlor is a chlorinated hydrocarbon insecticide with registered uses on tomatoes, corn, cucumbers, cauliflower, lettuce, carrots, beans, eggplant, endive, squash, broccoli, cabbage, peppers, potatoes, radishes, non-crop areas, and ornamental plants (NPIRS, 1988). Methoxychlor is almost non-toxic with an acute oral LD<sub>50</sub> for rats of 6000 mg/Kg body weight (Toxicity Category IV). Methoxychlor is widely used because of its long residual action against many species of insects and its low toxicity to humans and warmblooded animals (Berg, 1985). Methoxychlor has a very low accumulation rate in birds and mammals and relatively low avian toxicity. Methoxychlor is found to be degraded in natural waters in a few weeks or less (EPA, 1986d). During a runoff event, methoxychlor could be transported in appreciable proportion in the soil (Stewart, 1975).

**Methyl Bromide:** Methyl bromide is a restricted use halogenated hydrocarbon fumigant with registered uses on tomatoes, eggplant, broccoli, citrus, pineapple, peppers, lettuce, carrots, cauliflower, ornamental turf and lawn grasses, ornamental plants and non-crop areas (NPIRS, 1988). Methyl bromide has action as an acaricide, fungicide, herbicide, insecticide, nematocide, and rodenticide. Methyl bromide is moderately toxic with an acute oral LD<sub>50</sub> for rats of 214 mg/Kg body weight (Toxicity Category II). Methyl bromide is not expected to run off fields to surface water because of application methods (EPA, 1986e). Most of the methyl bromide applied to soil diffuse into the atmosphere. Some hydrolysis and reaction with soil components may occur. Methyl bromide has a half-life of greater than 55 days in water near neutral pH at 15°C. The half-life decreases rapidly with increasing temperature (US DHHS, 1981).

**Methyl Parathion:** Methyl parathion is a restricted use organophosphorus insecticide with registered uses on tomatoes, celery, cucumbers, peppers, beans, corn, lettuce, broccoli, cabbage, and rice (NPIRS, 1988). Methyl parathion is highly toxic with an acute oral LD<sub>50</sub> for rats between 4.5 and 16 mg/Kg body weight (Toxicity Category I). Methyl parathion is also considered highly toxic to aquatic invertebrates and birds. Insufficient information is available for the analysis of the environmental fate of methyl parathion (EPA, 1986f). During a runoff event, methyl parathion could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Metolachlor:** Metolachlor is a chloracetanilide selective herbicide with registered uses on citrus, beans, ornamental plants, corn and potatoes (NPIRS, 1988). Metolachlor is slightly toxic with an acute oral LD<sub>50</sub> for rats of 2780 mg/Kg body weight (Toxicity Category III). Available data are insufficient to assess the environmental fate of metolachlor (EPA, 1987a).

**Metribuzin:** Metribuzin is a non-restricted use triazine herbicide with registered uses on potatoes, carrots, corn, tomatoes, and sugarcane (NPIRS, 1988). Metribuzin is slightly toxic with an acute oral LD<sub>50</sub> for rats between 2200 and 2345 mg/Kg body weight (Toxicity Category III). Metribuzin is moderate to slightly toxic to birds and moderately toxic to freshwater fish and invertebrates. Metribuzin is moderately adsorbed on soils with high clay and/ or organic matter content. Metribuzin is readily leached in sandy soils low in organic matter content. Microbial breakdown appears to be the major mechanism by which metribuzin is lost from soils. Half-life varies with soil type and climatic conditions, however, at normal use rates the soil half-life is one to two months. Soil breakdown occurs fastest under



aerobic conditions and at comparatively high temperatures. Available data show that metribuzin has a potential to contaminate ground water in soils low in organic and clay content (EPA, 1985e). In pond studies, the half-life of metribuzin was between 2.5 and 6.5 days (US DHHS, 1981). During a runoff event, metribuzin could be transported in appreciable proportion in the water (Stewart, 1975).

**Mevinphos:** Mevinphos or phosdrin is a restricted use organophosphorus contact and systemic insecticide-acaricide with registered uses on tomatoes, celery, corn, cucumbers, eggplant, lettuce, parsley, squash, okra, broccoli, cabbage, beans, potatoes, peppers, and citrus (NPIRS, 1988). Technical mevinphos is highly toxic with an acute oral LD<sub>50</sub> for rats of 1.4 mg/Kg body weight (Toxicity Category I). Mevinphos is rapidly hydrolyzed in alkaline solutions with half-lives of 70 hours or less. In the soil, mevinphos appears to be decomposed primarily by chemical hydrolysis with half-lives of 3 to 12 hours (US DHHS, 1981). During a runoff event, mevinphos could be transported in appreciable proportion in the water (Stewart, 1975).

**Monocrotophos:** Monocrotophos or azodrin is a restricted use organophosphorus insecticide and acaricide with registered uses on tomatoes, potatoes, and sugarcane (NPIRS, 1988). Monocrotophos is highly toxic with an acute oral LD<sub>50</sub> for rats between 18 and 23 mg/Kg body weight (Toxicity Category I). Monocrotophos is very highly toxic to birds and freshwater invertebrates and moderately toxic to freshwater fish. Monocrotophos hydrolyzed rapidly with a half-life of 14 to 21 days at pH 9 and 25°C, with the rate decreasing at lower pH's and increasing at higher temperatures. Degradation on soil exposed to natural sunlight is rapid with a half-life less than 7 days, and on dark control samples is slower with a half-life of approximately 30 days. Monocrotophos is mobile in soil, and although it degrades rapidly, it may possess potential for ground water contamination (EPA, 1985f). During a runoff event, monocrotophos could be transported in appreciable proportion in the water (Stewart, 1975).

**Oxamyl:** Oxamyl is a carbamate insecticide, acaricide, and nematicide with registered uses on peppers, potatoes, tomatoes, celery, cucumbers, eggplant, squash, citrus, pineapple, and ornamental plants (NPIRS, 1988). Oxamyl is highly toxic with an acute oral LD<sub>50</sub> for rats between 2.5 and 3.1 mg/Kg body weight (Toxicity Category I). Oxamyl is very highly toxic to birds. Oxamyl has been shown to leach and has been found in well water (EPA, 1987b). The half-life of oxamyl in river water varied from 12 hours to 2 days. The half-life in soil is highly variable, ranging from 6 to 39 days in some tests, depending on location, soil type, and moisture content (US DHHS, 1981).

**Paraquat:** Paraquat is a restricted use bipyridylium compound registered as a non-selective herbicide, defoliant, desiccant, and plant growth regulator (EPA, 1987c). Registered sites include tomatoes, corn, citrus, peppers, broccoli, cabbage, cauliflower, potatoes, sugarcane, bananas, papayas, pineapple, cucumbers, squash, eggplant, lettuce, beans, ornamental plants, avocados and non-crop areas (NPIRS, 1988). Paraquat is moderately toxic with an acute oral LD<sub>50</sub> for rats between 100 and 150 mg/Kg body weight (Toxicity Category II). Paraquat is moderately toxic to birds and aquatic invertebrates and slightly toxic to freshwater fish. Paraquat is stable to hydrolysis and photolysis in soil since it is rapidly and strongly bound to soil, particularly clay. Preliminary data indicates that paraquat has a half-life of greater than 2 weeks in water plus soil. Paraquat is immobile in silt loam and silty clay loam, and slightly mobile in sandy loam and potentially mobile in sandy soils extremely low in organic matter. The half-life of paraquat in water is approximately

23 weeks. Paraquat is not readily desorbed from the soil and is not likely to contaminate ground water in agricultural soils (EPA, 1987c). During a runoff event, paraquat could be transported in appreciable proportion in the soil (Stewart, 1975).

**Parathion:** Parathion is a restricted use organophosphorus insecticide with registered uses on tomatoes, celery, corn, cucumbers, eggplant, lettuce, squash, okra, broccoli, cabbage, citrus, sugarcane, avocado, rice, endive, mangos, pineapple, carrots, peppers, cauliflower, potatoes, beans, ornamental plants, and radishes (NPIRS, 1988). Parathion is highly toxic with an acute oral LD<sub>50</sub> for rats between 1.75 and 15.0 mg/Kg body weight (Toxicity Category I). Parathion is highly toxic to fish and birds. The available data provide insufficient information for the analysis of the environmental fate of parathion. However, parathion has little or no potential to contaminate ground water (EPA, 1986g). During a runoff event, parathion could be transported in appreciable proportion in the soil (Stewart, 1975).

**Perthane:** Perthane is a chlorinated hydrocarbon insecticide which was used on certain vegetable crops for looper control. The product has been discontinued (Berg, 1985). It was also used in various formulations for the control of moths and carpet beetles in the dry cleaning and textile markets. Perthane is almost non-toxic with an acute oral LD<sub>50</sub> for rats of 8170 body weight (Toxicity Category IV) (Buchel, 1983). During a runoff event, perthane could be transported in appreciable proportion in the soil (Stewart, 1975).

**Phorate:** Phorate is a restricted use organophosphorus insecticide and nematicide with registered uses on tomatoes, corn, potatoes, lettuce, beans, and sugarcane (NPIRS, 1988). Phorate is highly toxic with an acute oral LD<sub>50</sub> for rats between 1.4 and 3.7 mg/Kg body weight (Toxicity Category I). Phorate is very highly toxic to birds, freshwater fish, and aquatic invertebrates. Phorate has some potential to leach through soil and contaminate ground water, particularly where soils are sandy and aquifers are shallow (EPA, 1985g). Phorate undergoes hydrolysis, particularly in alkaline solutions (US DHHS, 1981). During a runoff event, phorate could be transported in appreciable proportion with both soil and water (Stewart, 1975).

**Prometryn:** Prometryn is a selective triazine herbicide registered for use on celery (NPIRS, 1988). Prometryn is slightly toxic with an acute oral LD<sub>50</sub> for rats between 1,802 and 2,076 mg/Kg body weight (Toxicity Category III). Prometryn is slightly toxic to freshwater invertebrates, and moderately toxic to fish. Insufficient data are available to fully characterize the environmental fate of prometryn. Available data indicates that prometryn has hydrolytic stability and is persistent in the soil. Leaching studies indicate that prometryn has intermediate mobility in sandy loam soils and is very mobile in sandy soils (EPA, 1987d). During a runoff event, prometryn could be transported in appreciable proportion in the soil (Stewart, 1975).

**Simazine:** Simazine is a triazine herbicide with registered uses on avocado, sugarcane, ornamental turf and lawn grasses, ornamental plants, non-crop areas, and citrus (NPIRS, 1988). Simazine is almost non-toxic with an acute oral LD<sub>50</sub> for rats greater than 15,380 mg/Kg body weight (Toxicity Category IV). Simazine is not very toxic to nontarget insects, birds, or estuarine and marine organisms. Simazine is more readily adsorbed on muck or clay soils than in soils of low clay and organic matter content. The downward movement or leaching of simazine is limited by its low water solubility and adsorption to certain soil constituents. Little if any lateral movement in soil is expected, but simazine can be washed along with soil particles. In soils, microbial activity possibly accounts for decomposition of a significant

amount of simazine. The average half-life of simazine under anaerobic soil and aerobic soil conditions is 12 weeks and 8 to 12 weeks, respectively. The average half-life for simazine in ponds is 30 days (EPA, 1984g). During a runoff event, simazine could be transported in appreciable proportion in the soil (Stewart, 1975).

**Toxaphene:** Toxaphene is a restricted use insecticide consisting of a complex mixture of polychlorinated camphene derivatives containing 67 to 69 percent chlorine. As of November 1982, major continued uses for toxaphene are limited to use on cattle and sheep as dips for scabies, emergency use on armyworms, cutworms, and grasshoppers in cotton, corn, and small grains. Toxaphene is moderately toxic with an acute oral LD<sub>50</sub> for rats of 69 mg/Kg body weight (Toxicity Category II) (Berg, 1985). However, the bioaccumulation potential level in aquatic species is high and moderate in mammals (US DHHS, 1981). An inclusive assessment of the fate of the pesticide toxaphene in aquatic environments is complicated because toxaphene is a complex mixture of polychlorinated camphene derivatives of different physical properties and environmental behavior. Toxaphene is very stable to biological and chemical processes in aerobic environmental systems, but it does undergo partial reduction (loss of chloride content) in anaerobic environments. A dominant process in aquatic environments is direct sorption on hydrosol or sorption onto particulates followed by deposition into hydrosol where biological and possibly chemical reduction occurs. The rate of loss of toxaphene from aquatic systems will then be partially determined by particulate loading and quality of the water body; shallow, particulate laden, eutrophic waters give maximum transformation rates of toxaphene, with half-lives on the order of a few months for some components. The physical properties and chlorinated functionality of the individual toxaphene structures will govern which components will be sorbed and then subsequently reduced. The finding of some toxaphene components in hydrosols and aquatic species after several years indicates that bioaccumulation in the food chain may occur. Unless clear evidence proves otherwise, the absence of acute toxicity effects of toxaphene should not be interpreted as indicating that all toxaphene has been degraded and chronic toxic effects are absent (Callahan et al., 1979). Toxaphene is relatively persistent in soil with half-lives ranging up to 20 years have been reported (US DHHS, 1981). During a runoff event, toxaphene could be transported in appreciable proportion in the soil (Stewart, 1975).

**Trifluralin:** Trifluralin is a dinitroaniline selective, preemergence herbicide with registered uses on celery, sugarcane, tomatoes, okra, broccoli, cabbage, cucumbers, beans, ornamental turf and lawn grasses, ornamental plants, peppers, cauliflower, potatoes, non-crop areas, and citrus (NPIRS, 1988). Trifluralin is almost non-toxic with an acute oral LD<sub>50</sub> for rats of greater than 10,000 mg/Kg body weight (Toxicity Category IV) (Berg, 1985). Trifluralin readily decomposes when aqueous solutions are exposed to sunlight and readily volatilized and photodegraded in the soil environment. Low residues may persist in certain soils after repeated annual applications. The factors influencing the persistence of trifluralin include the soils organic matter content, its moisture, temperature, and the methods by which the herbicide was incorporated into it (US DHHS, 1981). Trifluralin is extremely resistant to leaching with little, if any lateral movement in the soil (US DHHS, 1981; Thomson, 1983). During a runoff event, trifluralin could be transported in appreciable proportion in the soil (Stewart, 1975).

**Trithion:** Trithion or carbophenothion is a restricted use organophosphorus insecticide and acaricide with registered uses on beans, citrus, corn, cucumbers, eggplant, squash, tomatoes, and ornamental turf and plants (NPIRS, 1988). Trithion is highly toxic with an acute oral LD<sub>50</sub> for rats between 7 and 91 mg/Kg body weight

(Toxicity Category I) (US DHHS, 1981). Trithion is characterized as very highly toxic to freshwater and marine/estuarine organisms and highly toxic to upland gamebirds. Preliminary data indicate that trithion is relatively immobile in sandy loam soils, however, the available data are insufficient to fully assess the environmental fate of trithion (EPA, 1984h). A half-life of greater than 100 days has been reported for residues of trithion in soil. Trithion is 50 percent hydrolyzed in 115 days in distilled water (US DHHS, 1981). During a runoff event, trithion could be transported in an appreciable proportion in the soil (Stewart, 1975).